ORIGINAL ARTICLE

Investigating the Relationship between Working Memory and Grammar in Children with High-Functioning Autism

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ABSTRACT

Objectives: Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by impairments in communication, social interaction, and executive functions. Individuals with High-Functioning Autism (HFA) often demonstrate average or above-average intelligence and typical language development. However, difficulties in social communication persist. Previous studies have indicated that children with HFA exhibit challenges in language, particularly in grammar and vocabulary, which may be associated with executive dysfunction, including deficits in Working Memory (WM). Therefore, the present study aimed to investigate the relationship between verbal WM and grammatical abilities in Persian-speaking children with HFA.

Materials & Methods: Twenty monolingual Persian-speaking children diagnosed with HFA, who met the inclusion criteria, were recruited for the study. Morpho-syntactic abilities were assessed through the collection of speech samples analyzed using Persian Developmental Sentence Scoring (PDSS). Additionally, Phonological Working Memory (PWM) tasks, including direct and reverse recall of numbers and repetition of non-words, were administered. Statistical analyses were performed using SPSS software to examine correlations between PWM and grammatical skills.

Results: The highest significant correlation was observed between the PDSS and the repetition of three-syllable non-words, while the lowest correlation was found with the immediate repetition of one-syllable non-words. ($r = 0.594$, $p < 0.05$). Furthermore, most PDSS subtests demonstrated statistically significant correlations with PWM tasks, with correlation coefficients varying from weak to strong.

Conclusion: This study concluded that HFA children experience difficulties in their grammatical skills, and a significant relationship is observed between their PWM and grammatical abilities, underscoring the importance of considering PWM in language intervention strategies, particularly targeting grammatical development in these children.

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Introduction

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition, affecting communication skills, social interactions, as well as cognitive and language abilities (1). Individuals with ASD often exhibit restricted and repetitive behaviors and may experience deficits in Executive Functioning (EF) (2, 3). Although symptom onset can vary, signs typically

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become evident by the age of two (4). Asperger Syndrome (AS), now often referred to as High-Functioning Autism (HFA), is a subtype of ASD characterized primarily by impaired social interaction. Individuals with HFA generally demonstrate average or above-average intelligence and do not exhibit significant delays in language or cognitive development (5, 6).

Although many linguistic sub-skills may be intact in individuals with HFA, several studies suggest that children with HFA often experience difficulties with language and communication, particularly in the domains of grammar and vocabulary (5). One prominent framework for understanding these challenges is the executive dysfunction theory. Executive functions encompass processes such as goal formation, planning, implementation of goal-directed behaviors, and cognitive flexibility. According to this theory, individuals with autism may exhibit varying degrees of impairment in these executive processes (7, 8).

Working Memory (WM), a core component of executive function, is defined as a temporary storage system, actively maintaining and manipulating multiple pieces of transient information under attentional control. WM plays a crucial role in numerous cognitive activities, including planning, attention, and language processing (9, 10). Its role is critical for grammatical development, as it enables individuals to retain and apply grammatical rules and structures during real-time language comprehension and production (11, 12).

Research on WM in individuals with ASD has produced mixed findings. Some studies report impairments in both visual-spatial and verbal WM (13, 14), while others do not. These discrepancies may be attributed to differences in factors, such as participant age, IQ, task type, or autism subtypes (15). Additionally, Tavares et al. found that children with HFA demonstrate significantly poorer performance in attentional control compared to their typically developing (TD) peers (16). Notably, few studies have conducted a comprehensive investigation into the linguistic competencies of children with HFA, specifically regarding their grammatical proficiency (5).

Several studies have investigated the relationship between WM and language abilities in children with ASD, with some, specifically focusing on the association between WM and grammar in children with HFA. For instance, Dillige et al. observed that WM deficits in children with HFA negatively impact their syntactic performance, and further demonstrated that alleviating these deficits can lead to improvements in syntactic ability (17). Similarly, Dahlgren et al. demonstrated that WM training can lead to improvements in language skills in this population (18). More recently, Delage et al. examined the effects of WM intervention on syntax in children with ASD. Their findings indicated that WM training not only improved performance on untrained WM tasks but also resulted in significant gains in syntactic abilities (19).

In summary, existing research suggests an association between working WM and grammatical abilities in children with ASD, indicating that targeted interventions to enhance WM may lead to improvements in grammar. Given the critical role of WM in supporting grammatical skills, the present study aims to investigate the relationship between PWM and grammar in Persian-speaking children with HFA.

Materials & Methods

Study design

This cross-sectional descriptive-analytical study assessed the grammatical abilities and Phonological Working Memory of children with HFA who met the predetermined inclusion criteria.

Participants

The present study recruited a cohort of children with HFA who were referred to several hospitals and academic medical centers in Mashhad, Khorasan Razavi Province, Iran. Participants were selected through convenience sampling, with inclusion contingent upon their availability. Each child received an HFA diagnosis from a qualified psychiatrist using the Gilliam Autism Rating Scale-Third Edition (GARS-3). Participants were included in the study based on predefined inclusion criteria.

All participants were monolingual Persian speakers with no history of mental health disorders, seizures, epilepsy, head trauma, or other neurological conditions. Additionally, they were screened for vision and hearing impairments. The absence of these conditions was verified through medical records, parental interviews, and evaluations conducted by a speech and language pathologist. Furthermore, the children were assessed for any motor or structural abnormalities of the speech organs using the standardized Persian version of the Robbins-Klee assessment (20). Only children in good general health who could produce at least 50 recognizable sentences during their speech assessment were eligible to participate. Ultimately, twenty children with HFA, aged between 7 and 9.6 years, who met these inclusion criteria were enrolled. Table 1 provides a summary of the participants' demographic characteristics.

Investigating grammar level

This study employed the Persian version of the Developmental Sentence Scoring test (PDSS), standardized by Jalilevand et al. (2016), to assess the morpho-syntactic abilities of Persian-speaking children with HFA (21). The PDSS is a validated measure designed to evaluate morpho-syntactic development in children aged between two and six years and 11 months (22). After obtaining consent from the children's parents for their participation in the study, to calculate the PDSS scores for children with HFA, speech samples were collected during individual sessions aimed at assessing their grammatical proficiency. The examiner engaged the child in conversation using various toys, pictures, and picture books to facilitate natural dialogue. Each speech sample was required to contain at least fifty recognizable sentences; therefore, the examiner continued the interaction until this criterion was satisfied. The duration of these sessions varied from 20 to 60 minutes, depending on each child's communication style. Following data collection, the language samples were transcribed and analyzed. PDSS scores were computed overall, as well as for individual subtests, including verb morphology, verb prefixes, conjunctions and prepositions, pronouns, question words, morphemes, sentence types, and sentence structures.

Table 1. Demographics of participants

Total number (N)	Female/male (N)	Mean age ± Std Deviation (Years)
20	8/12	8.41±0.73

Table 2. Phonological working memory examination items

Direct recall of numbers	Reverse recall of numbers	One-syllable non-words	Two-syllable non-words	Three-syllable non-words
2-4-3	3-6	sax	juke	dimate
3-1-4-2	1-4-5	qæt	game	hæfæsi
2-1-4-5-3	3-5-8-1	af	guræb	tærkafol
2-5-3-6-4-8	2-4-3-6-7	zi	lian	oqlamus
5-1-4-7-3-2-6		ter	alpum	morfalid
2-4-7-3-1-6-8-5		sey	antur	bikulit
3-6-7-2-1-4-8-5-9		ot	gardom	mirati
		doxm	ærjal	delaxfan
		læst	xalgi	gofaye
		soqm	gelaxt	naporost

The PDSS assesses grammatical subcategories in Persian that are crucial for the morphological structure of words. These include grammatical morphemes, as well as words functioning as grammatical elements such as prepositions, conjunctions, pronouns, and interrogative words. Additionally, the PDSS evaluates verb usage in terms of verb structure and compound (linked) verbs, along with sentence type and sentence structure (21).

In calculating the PDSS, the score for each sentence is derived by summing the scores of its constituent grammatical components in Persian. The average developmental sentence score is then calculated by dividing the total sum of points across all sentences by the number of sentences. The scoring scale ranges from values greater than 1. In Persian, grammatical forms that typically emerge earlier in language development are assigned lower scores, while those that appear later receive higher scores. The minimum possible score is 1, and the maximum is 6, reflecting six developmental levels spanning approximately 24 to 60 months in six-month intervals (21, 23). For example, grammatical components appearing at the first developmental level (around 24 to 30 months) receive one point, those at the second level (around 30 to 36 months) receive two points, and so forth.

Assessment of PWM

In the present study, direct and reverse recall of numbers, as well as non-word repetition, were employed to assess PWM.

The direct and reverse number recall tests were adapted from the standardized assessment developed by Mikaeli and Farahani (2014), demonstrating a validity of 82% (24). Prior to each test, the examiner provided examples to ensure the child understood the tasks. For the direct number recall test, the examiner verbally presented a sequence of digits, which the child was required to repeat in the same order. The test began with sequences of three numbers and progressed up to nine. If the child successfully repeated a sequence, an additional digit was added. Conversely, if the child failed to correctly repeat a sequence twice consecutively, their score from the previous level was recorded. The reverse number recall test employed a similar procedure, beginning with two-digit sequences and extending to sequences of four digits. In this task, the child was instructed to recall and recite the numbers in reverse order.

For the non-word repetition task, this study utilized the test developed by Barikroo et al. (2013) (25), indicating a validity of 80% for seven-year-old children. During the assessment, the examiner presented a series of nonce words and required the child to repeat them verbatim. The test comprised 30 non-words in total: ten one-syllable, ten two-syllable, and ten three-syllable items. Non-word repetition was assessed under two conditions: Immediately following the examiner's presentation and after a five-second delay. Table 2 summarizes the tasks used to evaluate WM abilities.

Data collection conditions

Speech samples were collected in a quiet room with minimal distractions. Additionally, the child's favorite toys, pictures, and picture books were used during data collection to facilitate better cooperation.

Statistical analysis

The SPSS software (version 22) was used to analyze data. Descriptive statistics were used to obtain the mean, standard deviation, maximum and minimum scores in PDSS, its subtests, and PWM tasks. In Addition, the Pearson correlation test was performed to check the correlations between variables. The significance level in all tests was considered less than 0.05 ($p < 0.05$).

Results

PDSS scores

The mean, minimum, and maximum scores of the PDSS and each of its subtests for the 20 children with HFA who participated in the study are presented in Table 3.

As shown in Table 3, the mean PDSS was 6.07. The values of this index varied among HFA children, with a maximum score of 9 and a minimum score of 6.

Table 3. Mean, maximum & minimum values of PDSS and its subtests in 20 HFA children

	Mean (SD)	**Max. score**	**Min. Score**
PDSS	6.07(1.52)	9.10	3.12
Verbs morphology	57.30(12.82)	91	42
Prefix verbs	57.30(8.36)	43	8
Conjunctions & prepositions	36.15(21.48)	81	12
Pronouns	13.20(11.30)	43	3
Question words	0.80(1.28)	5	0
Morphemes	69.00(31.09)	144	10
Type of sentence	47.65(6.36)	56	31
Structure of sentences	50.30(5.90)	58	39

Table 4. Mean, maximum & minimum values of working memory tasks in 20 HFA children

	Mean (SD)	**Max. score**	**Min. Score**
Direct recall of numbers	2.85(1.59)	6	0
Reverse recall of numbers	0.65(1.04)	4	0
Immediate repetition of one-syllable non-words	9.80(.616)	10	8
Delayed repetition of one-syllable non-words	9.05(1.98)	10	4
Immediate repetition of two-syllable non-words	9.35(1.18)	10	7
Delayed repetition of two-syllable non-words	7.35(3.95)	10	0
Immediate repetition of three-syllable non-words	8.30(3.09)	10	0
Delayed repetition of three-syllable non-words	5.90(4.51)	10	0

Table 5. Correlation between PDSS and PWM tasks in HFA children

Working memory tasks	**PDSS**	
	r	**Sig.**
Direct recall of numbers	.457	.043
Reverse recall of numbers	.590	.006
Immediate repetition of one-syllable non-words	.159	.251
Delayed repetition of one-syllable non-words	.458	.021
Immediate repetition of two-syllable non-words	.379	.050
Delayed repetition of two-syllable non-words	.560	.010
Immediate repetition of three-syllable non-words	.568	.004
Delayed repetition of three-syllable non-words	.594	.006

PWM scores

Table 4 presents the mean, minimum, and maximum scores for the PWM tasks.

According to Table 4, among the PWM tasks assessed in children with HFA, in the non-word repetition section, the highest mean score was observed in the immediate repetition of one-syllable non-words (M = 9.80) and the lowest mean score was for delayed repetition of three-syllable non-words (M = 5.90), while in the direct and reverse number recall section, the highest mean score belonged to direct recall of numbers (M = 2.85) and the lowest mean score was recorded for the reverse number recall task (M = 0.65).

Correlation between PWM tasks and PDSS

The Pearson correlation coefficient was employed to examine the relationship between PDSS scores and performance on PWM tasks. The correlation coefficients (r) and corresponding significance levels (p-values) are presented in Table 5.

As shown in Table 5, the strongest significant correlation was observed between PDSS scores and the delayed repetition of three-syllable non-words ($r = 0.594$, $p < 0.05$). The weakest correlation was found with the immediate repetition of one-syllable non-words ($r = 0.159$), statistically insignificant.

Table 6. Correlation between PDSS subtests and phonological working memory tasks in HFA children

	Direct recall of numbers		**Backward recall of numbers**		**Immediate repetition of one-syllable non-words**		**Delayed repetition of one-syllable non-words**		**Immediate repetition of two-syllable non-words**		**Delayed repetition of two-syllable non-words**		**Immediate repetition of three-syllable non-words**		**Delayed repetition of three-syllable non-words**	
	r	**Sig.**	**r**	**Sig.**	**r**	**Sig.**	**r**	**Sig.**	**r**	**Sig.**	**r**	**Sig.**	**r**	**Sig.**	**r**	**Sig.**
Verbs morphology	.429	.059	.461	.041*	.168	.240	.435	.027*	.296	.102	.500	.025*	.513	.010*	.492	.028*
Verb prefixes	.594	.006*	.730	.000*	.172	.235	.491	.014*	.460	.021*	.655	.002*	.657	.001*	.504	.023*
Conjunctions/ prepositions	.830	.000*	.684	.001*	.209	.188	.423	.031*	.570	.004*	.685	.001*	.694	.000*	.460	.041*
Pronouns	.341	.141	.736	.000*	.203	.196	.248	.146	.427	.030*	.393	.086	.439	.027*	.492	.027*
Question words	.208	.380	.269	.252	.289	.108	.431	.029*	.028	.454	.232	.325	.212	.185	.434	.434
Morphemes	.296	.206	.377	.101	.352	.064	.555	.006*	.463	.020*	.614	.004*	.688	.000*	.715	.000*
Type of sentence	.581	.007*	.722	.000*	.492	.014*	.563	.005*	.336	.074	.571	.008*	.550	.006*	.460	.041*
Structure of sentences	.717	.000*	.810	.000*	.379	.050*	.544	.007*	.401	.040*	.625	.003*	.605	.002*	.503	.024*

Correlation between PWM tasks and PDSS subtests

The Pearson correlation test was used to examine the relationships between PDSS subtests and PWM tasks. Table 6 presents the correlation coefficients (r) and significance levels (p-values) for these variables.

According to Table 6, the verb morphology subtest showed the strongest to weakest correlations with the following PWM tasks: immediate repetition of three-syllable non-words ($r = 0.513$, $p < 0.05$), delayed repetition of two-syllable non-words ($r = 0.500$, $p < 0.05$), delayed repetition of three-syllable non-words ($r = 0.492$, $p < 0.05$), backward recall of numbers ($r = 0.461$, $p < 0.05$), delayed repetition of one-syllable non-words ($r = 0.435$, $p < 0.05$), direct recall of numbers ($r = 0.429$, $p > 0.05$), immediate repetition of two-syllable non-words ($r = 0.296$, $p > 0.05$) and immediate repetition of one-syllable non-words ($r = 0.168$, $p > 0.05$). For the verb prefixes subtest, the strongest to weakest correlations were observed with: Backward recall of numbers ($r = 0.730$, $p < 0.05$), immediate repetition of three-syllable non-words ($r = 0.657$, $p < 0.05$), delayed repetition of two-syllable non-words ($r = 0.655$, $p < 0.05$), direct recall of numbers ($r = 0.594$, $p < 0.05$), delayed repetition of three-syllable non-words ($r = 0.504$, $p < 0.05$), delayed repetition of one-syllable non-words ($r = 0.491$, $p < 0.05$), immediate repetition of two-syllable non-words ($r = 0.460$, $p < 0.05$), and immediate repetition of one-syllable non-words ($r = 0.172$, $p > 0.05$). For the conjunctions/prepositions subtest, the order of strongest to weakest correlations was as follows: Direct recall of numbers ($r = 0.830$, $p < 0.05$), immediate repetition of three-syllable non-words ($r = 0.694$, $p < 0.05$), delayed repetition of two-syllable non-words ($r = 0.685$, $p < 0.05$), backward recall of numbers ($r = 0.657$, $p < 0.05$), immediate repetition of two-syllable non-words ($r = 0.570$, $p < 0.05$), delayed repetition of three-syllable non-words ($r = 0.460$, $p < 0.05$), delayed repetition of one-syllable non-words ($r = 0.423$, $p < 0.05$), and immediate repetition of one-syllable non-words ($r = 0.209$, $p > 0.05$). For the pronouns subtest, the correlations in descending order were backward recall of numbers ($r = 0.736$, $p < 0.05$), delayed repetition of three-syllable non-words ($r = 0.492$, $p < 0.05$), immediate repetition of three-syllable non-words ($r = 0.439$, $p < 0.05$), immediate repetition of two-syllable non-words ($r = 0.427$, $p < 0.05$), delayed repetition of two-syllable non-words ($r = 0.393$, $p > 0.05$), direct recall of numbers ($r = 0.341$, $p > 0.05$), delayed repetition of one-syllable non-words ($r = 0.248$, $p > 0.05$), and immediate repetition of one-syllable non-words ($r = 0.203$, $p > 0.05$). For the question words subtest, the order of correlations was as follows: Delayed repetition of three-syllable non-words ($r = 0.434$, $p > 0.05$), delayed repetition of one-syllable non-words ($r = 0.431$, $p < 0.05$), immediate repetition of one-syllable non-words ($r = 0.289$, $p > 0.05$), backward recall of numbers ($r = 0.269$, $p > 0.05$), delayed repetition of two-syllable non-words ($r = 0.232$, $p > 0.05$), immediate repetition of three-syllable non-words ($r = 0.212$, $p > 0.05$), direct recall of numbers ($r = 0.208$, $p > 0.05$), and immediate repetition of two-syllable non-words ($r = 0.028$, $p > 0.05$). For the morphemes subtest, the correlations with PWM tasks, from strongest to weakest, were as follows: Delayed repetition of three-syllable non-words ($r = 0.715$, $p < 0.05$), immediate repetition of three-syllable non-words ($r = 0.688$, $p < 0.05$), delayed repetition of two-syllable non-words ($r = 0.614$, $p < 0.05$), delayed repetition of one-syllable non-words ($r = 0.555$, $p < 0.05$), immediate repetition of two-syllable non-words ($r = 0.463$, $p < 0.05$), backward recall of numbers ($r = 0.377$, $p > 0.05$), immediate repetition of one-syllable non-words ($r = 0.352$, $p > 0.05$), and direct recall of numbers ($r = 0.296$, $p > 0.05$). For the type of sentence subtest, the descending order of correlations was backward recall of numbers ($r = 0.722$, $p < 0.05$), direct recall of numbers ($r = 0.581$, $p < 0.05$), delayed repetition of two-syllable non-words ($r = 0.571$, $p < 0.05$), delayed repetition of one-syllable non-words ($r = 0.563$, $p < 0.05$), immediate repetition of three-syllable non-words ($r = 0.550$, $p < 0.05$), immediate repetition of one-syllable non-words ($r = 0.492$, $p < 0.05$), delayed repetition of three-syllable non-words ($r = 0.460$, $p < 0.05$), and immediate repetition of two-syllable non-words ($r = 0.336$, $p > 0.05$). Finally, for the structure of sentences subtest, the correlations were as follows: Backward recall of numbers ($r = 0.810$, $p < 0.05$), direct recall of numbers ($r = 0.717$, $p < 0.05$), delayed repetition of two-syllable non-words ($r = 0.625$, $p < 0.05$), immediate repetition of three-syllable non-words ($r = 0.605$, $p < 0.05$), delayed repetition of one-syllable non-words ($r = 0.544$, $p < 0.05$), delayed repetition of three-syllable non-words ($r = 0.503$, $p < 0.05$), immediate repetition of two-syllable non-words ($r = 0.401$, $p < 0.05$), and immediate repetition of one-syllable non-words ($r = 0.379$, $p < 0.05$).

Figure 1 illustrates the correlations between the PDSS subtests and non-word repetition tasks, and Figure 2 depicts the correlations between these subtests and both direct and reverse number recall tasks in children with HFA in the present study.

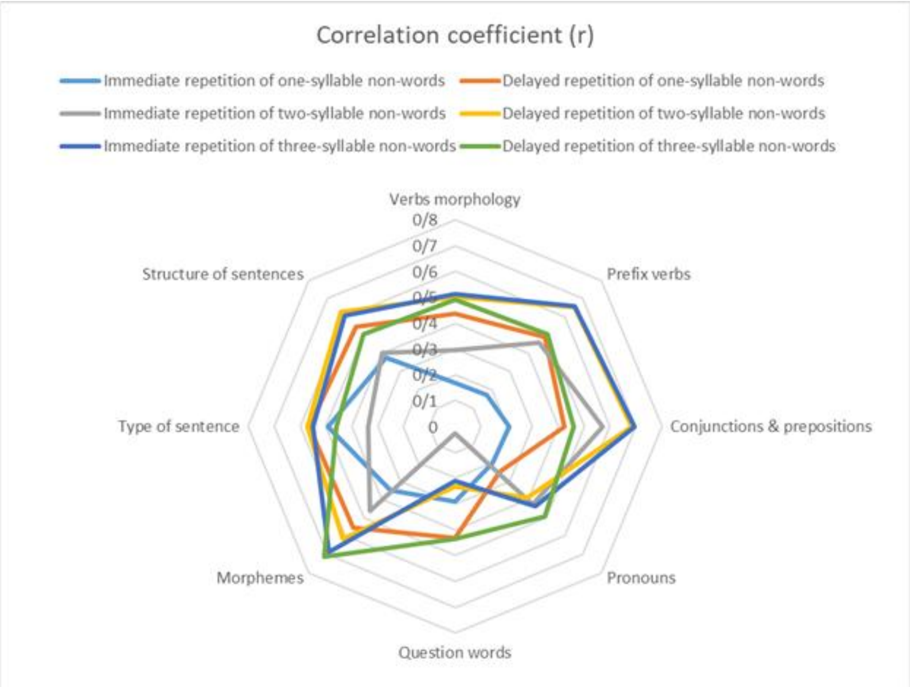

Figure 1. Correlation between PDSS subtests and non-words repetition tasks

As illustrated in Figure 1, the strongest correlation was observed between the morphemes subtest and delayed repetition of three-syllable non-words, whereas the weakest correlation was found between the question words subtest and immediate repetition of two-syllable non-words.

Figure 2 illustrates that, for direct recall of numbers, the highest correlation was observed with the conjunctions and prepositions subtest, while the lowest correlation was with the question words subtest. Conversely, for reverse recall of numbers, the strongest correlation was with the structure of sentences subtest, and the weakest was again with the question words subtest.

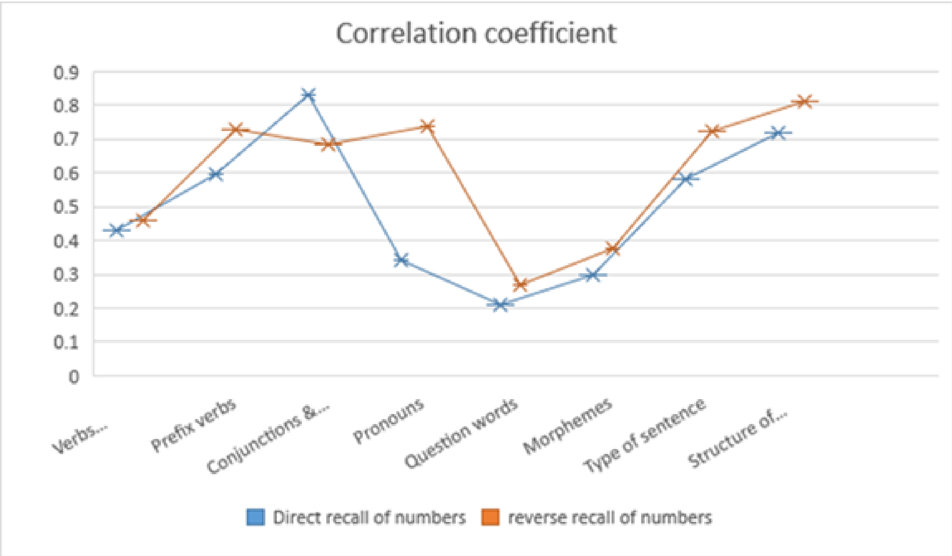

Figure 2. Correlation between PDSS subtests and direct & reverse recall of numbers

Discussion

PDSS and its subtests

In this study, the mean PDSS score for children with HFA was lower than that reported for TD children at younger ages by Jalilevand et al. (2016) (21), indicating that even in the absence of intellectual disabilities, children with HFA demonstrate significant grammatical deficits. In contrast to several reported studies (26, 27), this finding indicates that the challenges extend beyond pragmatic or semantic domains to encompass structural aspects of language.

A granular examination of the PDSS subtests demonstrated that children with HFA exhibited a lower frequency of utilizing grammatical morphemes, conjunctions, and prepositions compared to their TD peers, even at earlier developmental stages. An exception was noted for verb prefixes, where the disparity was less significant. This pattern suggests that children with HFA not only employ simpler syntactic structures but also encounter difficulties with morphological aspects of language.

The obtained results are consistent with previous research. For instance, Durrleman and Franck (2015) reported that children with HFA are capable of producing grammatically correct sentences; however, these sentences often lack syntactic complexity (28). Similarly, studies by Lotfy et al. (2018) and Egisti et al. (2007) documented persistent difficulties among children with ASD in using pronouns and conjunctions, such as and, pointing to a reliance on simpler sentence structures. Research on grammatical morphology in spontaneous speech among children with ASD has also highlighted persistent challenges with both past and present tense usage (29, 30). However, some studies have demonstrated that children with HFA perform relatively well on tense morphemes during complex grammaticality judgment tasks, often outperforming children diagnosed with Autism Language Impairment (ALI) (31). These findings may suggest a distinct morpho-syntactic profile influenced by the presence of a general language impairment (31, 32). Modyanova's study (2017) supports this notion, showing that while children with HFA perform well on tense morpheme tasks, those with ALI exhibit significant difficulties, often resembling the performance of much younger TD children (33). Additionally, Hulsey (2020) reported that individuals with ASD experience notable challenges with grammatical markers for past tense. Interestingly, their difficulties in forming questions or statements using the verbs "be" and "do" were less pronounced than expected. The primary challenges emerged when participants were required to evaluate sentences lacking verb tense markers. Consequently, they frequently struggled with the use of verb tense markers, particularly irregular verbs, resulting in frequent errors (34). One possible explanation for the discrepancies between the present study and previous research is the more detailed examination of grammatical components in the current study. Specifically, rather than focusing solely on verb tense, this study investigated two separate subsets—verb morphology and verb prefixes—each encompassing a broader range of grammatical elements.

The obtained findings underscore the complexities of grammatical development in children with HFA and highlight the necessity for targeted interventions addressing these specific language challenges. To this end, it is essential both to conduct more detailed examinations of grammar in this population and to identify the factors that facilitate the improvement of their grammatical difficulties, thereby enhancing the efficacy and speed of intervention strategies.

Relationship between PDSS subtests and PWM

One of the key findings of this study was significant correlations between PDSS and nearly all PWM tasks, with the exception of immediate repetition of one-syllable non-words. Notably, according to Lovacov and Agadullin's (2021) classification, the correlations were observed to be large to moderate for the delayed repetition of three-syllable non-words, backward digit recall, immediate repetition of three-syllable non-words, delayed repetition of two-syllable non-words, delayed repetition of one-syllable non-words, and immediate repetition of two-syllable non-words tasks, respectively (35). Additionally, the correlation analysis between each PDSS subtest and the working-memory tasks indicated that better performance of children with HFA on PWM tasks is associated with their ability to produce more grammatically complex sentences; the capacity to recall items after a delay appears to be linked to using more complex sentence structures. For instance, as shown in the Results section, the most significant correlation was found between the delayed repetition of three-syllable non-words task and the morphemes subtest. This suggests that higher performance by children with HFA on a challenging PWM task corresponded to their ability to produce sentences with a greater number of morphemes, indicating increased sentence complexity. Archibald (2016) noted that limitations in WM may constrain the amount of linguistic detail that can be processed. Furthermore, difficulties in language development can increase the cognitive load on WM, particularly in retaining unfamiliar sounds and phonetic information (36).

Numerous studies have investigated the relationship between WM and language acquisition, particularly in the context of grammatical development. Dollaghan (1998) proposed that non-word repetition tasks serve as valuable clinical tools for identifying language impairments in children (37). Barends et al. (2013) reported that individuals with HFA experience WM difficulties, becoming more pronounced when processing complex information (10). Weismer et al. (2017) found that non-verbal WM is a strong predictor of morpho-syntactic processing abilities in children with ASD (12). Additionally, Delage et al. (2022) demonstrated that enhancing WM can lead to significant improvements in both syntactic performance and previously unexplored WM tasks (19). Taken together, these findings, along with the study results, underscore the association between PWM and grammatical skills in children with HFA. Accordingly, it appears that speech and language pathologists who address grammatical difficulties in this population may achieve more rapid progress by assessing and incorporating interventions targeting PWM.

In Conclusion

This study highlights that children with HFA exhibit lower grammatical performance compared to TD children who are chronologically younger. It also reveals a relationship between their PWM and grammatical skills. Given this correlation, future research is recommended to investigate the effects of WM enhancement on the efficacy of grammar-focused therapeutic programs conducted by speech-language pathologists.

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Authors' Contributions

Nasibe Soltaninejad was responsible for: Writing (review & editing, original draft), Supervision, Project administration, Methodology, Investigation, Formal analysis, and Data curation. Davood Sobhanirad contributed through: Writing (review & editing), Project administration, Methodology, Investigation, and Data curation. Zahra Najafi and Najme Hoseini both provided support in: Writing (review & editing), Methodology, and Formal analysis.

Conflict of Interest

No conflict of interest.

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